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U. S. NAVAL ORDNANCE PLANT
Indianapolis, Indiana
RESEARCH AND TEST DEPARTMENT

CONVERSION DATA

Prepared by
THE NUMERICAL ANALYSIS BRANCH
of the
MATHEMATICS DIVISION

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These are the Results of Computations made and subject to extensive
attention and do not constitute a complete report in themselves.

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OND-P-1481 Navy-REFD 2ND, Great Lakes, IL

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INTRODUCTION


The conversion of measurements from one unit to another is an ever occurring operation in scientific research and development work. Over a period of years a number of conversion tables related to airborne fire control theories have been accumulated. These tables have been calculated under the authorization of many task assignments and are collected here for quick reference. The tables and graphs are in general self explanatory with the exception of the relative air density versus altitude tables. A brief explanation of these tables is therefore presented here.

RELATIVE AIR DENSITY

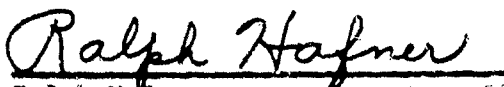
The determination of a relationship between the relative air density and altitude is a confusing matter since different "standard" atmospheres are in use. Thus the "standard" atmosphere adopted by the NACA (see NACA Report No. 218) establishes the specific weight of "standard" air to be 0.07651 lb./cu.ft. and the relative air density at sea level ($h = 0$) to be 1.000 at a temperature of 59° F and a pressure of 29.92 in. of mercury for dry air. In the computation of ballistic tables for gunnery a "standard" of 0.07513 lb./cu.ft. at 59° F and 29.53 in. of mercury with a relative humidity of 78% is assumed. It is, however, not related specifically to any altitude but presumably this would be the condition at sea level some place on the earth. Still a third "standard" is being considered for bomb trajectories. This standard specifies a specific weight of 0.078096 lb./cu.ft. at a temperature of 50° F and a pressure of 30.01 in. of mercury in a latitude of 45° N but relates the resulting relative air density of 1 to the altitude at sea level.

It is now possible to construct three tables of altitude versus relative air density based upon the above mentioned three reference densities. The only table which will be exhibited, however, will be that of the ballistic relative air density compared to the altitude of the NACA standard atmosphere.

Prepared by


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Approved by


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KNOTS to MPH to FT/SEC

$$1 \text{ KNOT} = \frac{6080}{5280} \text{ MPH} = \frac{6080}{3600} \text{ FT/SEC}$$

$$1 \text{ KNOT} = 1.151515 \text{ MPH} = 1.688889 \text{ FT/SEC}$$

$$\Delta \text{ MPH} = 5.757576 \quad \Delta \text{ FT/SEC} = 8.444444$$

	MPH	FT/SEC	MPH	FT/SEC	MPH	FT/SEC	MPH	FT/SEC	MPH	FT/SEC
	100		300		500		700		900	
0	115	169	345	507	575	844	806	1182	1036	1520
5	121	177	351	515	582	853	812	1191	1042	1528
10	127	186	357	524	587	861	818	1199	1048	1537
15	132	194	363	532	593	870	823	1208	1054	1545
20	138	203	368	540	599	878	829	1216	1059	1554
25	144	211	374	549	605	887	835	1224	1065	1562
30	150	220	380	557	610	895	841	1233	1071	1571
35	155	228	386	566	616	904	846	1241	1077	1579
40	161	236	392	574	622	912	852	1250	1082	1588
45	167	245	397	583	628	920	858	1258	1088	1596
50	173	253	403	591	633	929	864	1267	1094	1604
55	178	262	409	600	639	937	869	1275	1100	1613
60	184	270	415	608	645	946	875	1284	1105	1621
65	190	279	420	616	651	954	881	1292	1111	1630
70	196	287	426	625	656	963	887	1300	1117	1638
75	202	296	432	633	662	971	892	1309	1123	1647
80	207	304	438	642	668	980	898	1317	1128	1655
85	213	312	443	650	674	988	904	1326	1134	1664
90	219	321	449	659	679	996	910	1334	1140	1672
95	225	329	455	667	685	1005	915	1343	1146	1680
	200		400		600		800		1000	
0	230	338	461	676	691	1013	921	1351	1152	1689
5	236	346	466	684	697	1022	927	1360	1157	1697
10	242	355	472	692	702	1030	933	1368	1163	1706
15	248	363	478	701	708	1039	938	1376	1169	1714
20	253	372	484	709	714	1047	944	1385	1175	1723
25	259	380	489	718	720	1056	950	1393	1180	1731
30	265	388	495	726	725	1064	956	1402	1186	1740
35	271	397	501	735	731	1072	962	1410	1192	1748
40	276	405	507	743	737	1081	967	1419	1198	1756
45	282	414	512	752	743	1089	973	1427	1203	1765
50	288	422	518	760	748	1098	979	1436	1209	1773
55	294	431	524	768	754	1106	985	1444	1215	1782
60	299	439	530	777	760	1115	990	1452	1221	1790
65	305	448	535	785	766	1123	996	1461	1226	1799
70	311	456	541	794	772	1132	1002	1469	1232	1807
75	317	464	547	802	777	1140	1008	1478	1238	1816
80	322	473	553	811	783	1148	1013	1486	1244	1824
85	328	481	558	819	789	1157	1019	1495	1249	1832
90	334	490	564	828	795	1165	1025	1503	1255	1841
95	340	498	570	836	800	1174	1031	1512	1261	1849

ROC 6

MPH to FT/SEC to KNOTS

$$1 \text{ MPH} = \frac{5280}{3600} \text{ FT/SEC} = \frac{5280}{6080} \text{ KNOTS}$$

$$1 \text{ MPH} = 1.466667 \text{ FT/SEC} = .868421 \text{ KNOTS}$$

$$\Delta \text{ FT/SEC} = 7\frac{1}{3}$$

$$\Delta \text{ KNOTS} = 4.342105$$

	FT/SEC	KNOTS	FT/SEC	KNOTS	FT/SEC	KNOTS	FT/SEC	KNOTS	FT/SEC	KNOTS
	100		300		500		700		900	
0	147	87	440	251	733	434	1027	608	1320	782
5	154	91	447	265	741	439	1034	617	1327	786
10	161	96	455	269	748	443	1041	617	1335	790
15	169	100	462	274	755	447	1049	621	1342	795
20	176	104	469	278	763	452	1056	625	1349	799
25	183	109	477	282	770	456	1063	630	1357	803
30	191	113	484	287	777	460	1071	634	1364	808
35	198	117	491	291	785	465	1078	638	1371	812
40	205	122	499	295	792	469	1085	643	1379	816
45	213	126	506	300	799	473	1093	647	1386	821
50	220	130	513	304	807	478	1100	651	1393	825
55	227	135	521	308	814	482	1107	656	1401	829
60	235	139	528	313	821	486	1115	660	1408	834
65	242	143	535	317	829	491	1122	664	1415	838
70	249	148	543	321	836	495	1129	669	1423	842
75	257	152	550	326	843	499	1137	673	1430	847
80	264	156	557	330	851	504	1144	677	1437	851
85	271	161	565	334	858	508	1151	682	1445	855
90	279	165	572	339	865	512	1159	686	1452	860
95	286	169	579	343	873	517	1166	690	1459	864
	200		400		600		800		1000	
0	293	174	587	347	880	521	1173	695	1467	868
5	301	178	594	352	887	525	1181	699	1474	873
10	308	182	601	356	895	530	1188	703	1481	877
15	315	187	609	360	902	534	1195	708	1489	881
20	323	191	616	365	909	538	1203	712	1496	886
25	330	195	623	369	917	543	1210	716	1503	890
30	337	200	631	373	924	547	1217	721	1511	894
35	345	204	638	378	931	551	1225	725	1518	899
40	353	208	645	382	939	556	1232	729	1525	903
45	359	213	653	386	946	560	1239	734	1533	907
50	367	217	660	391	953	564	1247	738	1540	912
55	374	221	667	395	961	569	1254	742	1547	916
60	381	226	675	399	968	573	1261	747	1555	921
65	389	230	682	404	975	577	1269	751	1562	925
70	396	234	689	408	983	582	1276	756	1569	929
75	403	239	697	412	990	586	1283	760	1577	934
80	411	243	704	417	997	591	1291	764	1584	938
85	418	247	711	421	1005	595	1298	769	1591	942
90	425	252	719	426	1012	599	1305	773	1599	947
95	433	256	726	430	1019	604	1313	777	1606	951

FT/SEC to MPH to KNOTS

$$1 \text{ FT/SEC} = \frac{3600}{5280} \text{ MPH} = \frac{3600}{6080} \text{ KNOTS}$$

$$1 \text{ FT/SEC} = .681818 \text{ MPH} = .592105 \text{ KNOTS}$$

$$\Delta \text{ MPH} = 6.818182$$

$$\Delta \text{ KNOTS} = 5.921053$$

	MPH	KNOTS	MPH	KNOTS	MPH	KNOTS	MPH	KNOTS	MPH	KNOTS
	200		600		1000		1400		1800	
0	136	118	409	355	682	592	955	829	1227	1066
10	143	124	416	361	689	598	961	835	1234	1072
20	150	130	423	367	695	604	968	841	1241	1078
30	157	136	430	373	702	610	975	847	1248	1084
40	164	142	436	379	709	616	982	853	1255	1089
50	170	148	443	385	716	622	989	859	1261	1095
60	177	154	450	391	723	628	995	864	1268	1101
70	184	160	457	397	730	634	1002	870	1275	1107
80	191	166	464	403	736	639	1009	876	1282	1113
90	198	172	470	409	743	645	1016	882	1289	1119
	300		700		1100		1500		1900	
0	205	178	477	414	750	651	1023	888	1295	1125
10	211	184	484	420	757	657	1030	894	1302	1131
20	218	189	491	426	764	663	1036	900	1309	1137
30	225	195	498	432	770	669	1043	906	1316	1143
40	232	201	505	438	777	675	1050	912	1323	1149
50	239	207	511	444	784	681	1057	918	1330	1155
60	245	213	518	450	791	687	1064	924	1336	1161
70	252	219	525	456	798	693	1070	930	1343	1166
80	259	225	532	462	805	699	1077	936	1350	1172
90	266	231	539	468	811	705	1084	941	1357	1178
	400		800		1200		1600		2000	
0	273	237	545	474	818	711	1091	947	1364	1184
10	280	243	552	480	825	716	1098	953	1370	1190
20	286	249	559	486	832	722	1105	959	1377	1196
30	293	255	566	491	839	728	1111	965	1384	1202
40	300	261	573	497	845	734	1118	971	1391	1208
50	307	266	580	503	852	740	1125	977	1398	1214
60	314	272	586	509	859	746	1132	983	1405	1220
70	320	278	593	515	866	752	1139	989	1411	1226
80	327	284	600	521	873	758	1145	995	1418	1232
90	335	290	607	527	880	764	1152	1001	1425	1238
	500		900		1300		1700		2100	
0	341	296	614	533	886	770	1159	1007	1432	1243
10	348	302	620	539	893	776	1166	1013	1439	1249
20	355	308	627	545	900	782	1173	1018	1445	1255
30	361	314	634	551	907	788	1180	1024	1452	1261
40	368	320	641	557	914	793	1186	1030	1459	1267
50	375	326	648	563	920	799	1193	1036	1466	1273
60	382	332	655	568	927	805	1200	1042	1473	1279
70	389	338	661	574	934	811	1207	1048	1480	1285
80	395	343	668	580	941	817	1214	1054	1486	1291
90	402	349	675	586	948	823	1220	1060	1493	1297

ROC C

DEGREES to MILS

$$1 \text{ DEGREE} = \pi 1000 / 180 \text{ MILS} = 17.4523293 \text{ MILS}$$

Degrees					Minutes		Seconds		
0	0.0000	60	1047.1978	120	2094.3951	0	0.0000	0	.0000
1	17.4533	61	1064.6508	121	2111.8484	1	0.2909	1	.0048
2	34.9066	62	1082.1041	122	2129.3017	2	0.5818	2	.0097
3	52.3599	63	1099.5574	123	2146.7550	3	0.8727	3	.0145
4	69.8132	64	1117.0107	124	2164.2083	4	1.1636	4	.0194
5	87.2665	65	1134.4640	125	2181.6616	5	1.4544	5	.0242
6	104.7198	66	1151.9173	126	2199.1149	6	1.7453	6	.0291
7	122.1730	67	1169.3706	127	2216.5682	7	2.0362	7	.0339
8	139.6263	68	1186.8239	128	2234.0214	8	2.3271	8	.0388
9	157.0796	69	1204.2772	129	2251.4747	9	2.6180	9	.0436
10	174.5329	70	1221.7305	130	2268.9280	10	2.9089	10	.0485
11	191.9862	71	1239.1838	131	2286.3813	11	3.1998	11	.0533
12	209.4395	72	1256.6371	132	2303.8346	12	3.4907	12	.0582
13	226.8928	73	1274.0904	133	2321.2879	13	3.7815	13	.0630
14	244.3461	74	1291.5436	134	2338.7412	14	4.0724	14	.0679
15	261.7994	75	1308.9969	135	2356.1945	15	4.3633	15	.0727
16	279.2527	76	1326.4502	136	2373.6478	16	4.6542	16	.0776
17	296.7060	77	1343.9035	137	2391.1011	17	4.9451	17	.0824
18	314.1593	78	1361.3568	138	2408.5544	18	5.2360	18	.0873
19	331.6126	79	1378.8101	139	2426.0077	19	5.5269	19	.0921
20	349.0659	80	1396.2634	140	2443.4610	20	5.8178	20	.0970
21	366.5191	81	1413.7167	141	2460.9142	21	6.1087	21	.1018
22	383.9724	82	1431.1700	142	2478.3675	22	6.3995	22	.1067
23	401.4257	83	1448.6233	143	2495.8208	23	6.6904	23	.1115
24	418.8790	84	1466.0766	144	2513.2741	24	6.9813	24	.1164
25	436.3323	85	1483.5299	145	2530.7274	25	7.2722	25	.1212
26	453.7856	86	1500.9832	146	2548.1807	26	7.5631	26	.1261
27	471.2389	87	1518.4364	147	2565.6340	27	7.8540	27	.1309
28	488.6922	88	1535.8897	148	2583.0873	28	8.1449	28	.1357
29	506.1455	89	1553.3430	149	2600.5406	29	8.4358	29	.1406
30	523.5988	90	1570.7963	150	2617.9939	30	8.7266	30	.1454
31	541.0521	91	1588.2496	151	2635.4472	31	9.0175	31	.1503
32	558.5054	92	1605.7029	152	2652.9005	32	9.3084	32	.1551
33	575.9587	93	1623.1562	153	2670.3538	33	9.5993	33	.1600
34	593.4119	94	1640.6095	154	2687.8070	34	9.8902	34	.1648
35	610.8652	95	1658.0628	155	2705.2603	35	10.1811	35	.1697
36	628.3185	96	1675.5161	156	2722.7136	36	10.4720	36	.1745
37	645.7718	97	1692.9694	157	2740.1669	37	10.7629	37	.1794
38	663.2251	98	1710.4227	158	2757.6202	38	11.0538	38	.1842
39	680.6784	99	1727.8760	159	2775.0735	39	11.3446	39	.1891
40	698.1317	100	1745.3293	160	2792.5268	40	11.6355	40	.1939
41	715.5850	101	1762.7826	161	2809.9801	41	11.9264	41	.1988
42	733.0383	102	1780.2358	162	2827.4334	42	12.2173	42	.2036
43	750.4916	103	1797.6891	163	2844.8867	43	12.5082	43	.2085
44	767.9449	104	1815.1424	164	2862.3400	44	12.7991	44	.2133
45	785.3982	105	1832.5957	165	2879.7933	45	13.0900	45	.2182
46	802.8515	106	1850.0490	166	2897.2466	46	13.3809	46	.2230
47	820.3047	107	1867.5023	167	2914.6999	47	13.6717	47	.2279
48	837.7580	108	1884.9556	168	2932.1531	48	13.9626	48	.2327
49	855.2113	109	1902.4089	169	2949.6064	49	14.2535	49	.2376
50	872.6646	110	1919.8622	170	2967.0597	50	14.5444	50	.2424
51	890.1179	111	1937.3155	171	2984.5130	51	14.8353	51	.2473
52	907.5712	112	1954.7688	172	3001.9663	52	15.1262	52	.2521
53	925.0245	113	1972.2221	173	3019.4196	53	15.4171	53	.2570
54	942.4778	114	1989.6753	174	3036.8729	54	15.7080	54	.2618
55	959.9311	115	2007.1286	175	3054.3262	55	15.9989	55	.2666
56	977.3844	116	2024.5819	176	3071.7795	56	16.2897	56	.2715
57	994.8377	117	2042.0352	177	3089.2328	57	16.5806	57	.2763
58	1012.2910	118	2059.4885	178	3106.6861	58	16.8715	58	.2812
59	1029.7443	119	2076.9418	179	3124.1394	59	17.1624	59	.2860
60	1047.1978	120	2094.3951	180	3141.5927	60	17.4533	60	.2909

MILLIRADIANS to DEGREES

$$1 \text{ MIL} = \frac{180}{\pi} 10^{-3} \text{ DEGREES} = .057296 \text{ DEGREES}$$

Decimal Values of Degrees

	1000 mils	100 mils	10 mils	mils	$\frac{1}{10}$ mil
1	57.2958	5.7296	.5730	.0573	.0057
2	114.5916	11.4592	1.1459	.1146	.0115
3	171.8873	17.1887	1.7189	.1719	.0172
4	229.1831	22.9183	2.2918	.2292	.0229
5	286.4789	28.6479	2.8648	.2865	.0286
6	343.7747	34.3775	3.4377	.3438	.0344
7	401.0705	40.1070	4.0107	.4011	.0401
8	458.3662	45.8366	4.5837	.4584	.0458
9	515.6620	51.5662	5.7566	.5157	.0516

Degrees, Minutes, and Seconds

	1000 mils	100 mils	10 mils	mils	$\frac{1}{10}$ mil
1	57°17'44.8"	5°43'46.5"	0°34'22.6"	0°3'26.3"	0°0'20.6"
2	114°35'29.6"	11°27'33.0"	1°8'45.3"	0°6'52.5"	0°0'41.3"
3	171°53'14.4"	17°11'19.4"	1°43'07.9"	0°10'18.8"	0°1'01.9"
4	229°10'59.2"	22°55'05.9"	2°17'30.6"	0°13'45.1"	0°1'22.5"
5	286°28'44.0"	28°38'52.4"	2°51'53.2"	0°17'11.3"	0°1'43.1"
6	343°46'28.8"	34°22'38.9"	3°26'15.9"	0°20'37.6"	0°2'03.8"
7	401°4'13.6"	40°6'25.4"	4°0'38.5"	0°24'03.9"	0°2'24.4"
8	458°21'58.4"	45°50'11.8"	4°35'1.2"	0°27'30.1"	0°2'45.0"
9	515°39'43.3"	51°33'58.3"	5°9'23.3"	0°30'56.4"	0°3'06.6"

THE SPEED OF SOUND

I. AS A FUNCTION OF TEMPERATURE

C°	FT/SEC	MPH	KNOTS
0	1088	741.8	644.2
20	1129	769.8	668.5
100	1266	863.2	749.6
500	1814	1237	1074
1000	2297	1566	1360

II. AS A FUNCTION OF ALTITUDE

h (1000 ft)	FT/SEC	MPH	KNOTS	h (1000 ft)	FT/SEC	MPH	KNOTS
0	1117	761.6	661.4	21	1033	704.5	611.6
1	1113	759.0	659.0	22	1029	701.6	609.3
2	1109	756.3	656.6	23	1025	698.8	606.9
3	1105	753.7	654.3	24	1021	695.9	604.5
4	1102	751.0	652.5	25	1017	693.1	602.2
5	1098	748.4	650.1	26	1012	690.2	599.2
6	1094	745.7	647.8	27	1008	687.3	596.8
7	1090	743.0	645.4	28	1004	684.4	594.5
8	1086	740.4	643.0	29	999	681.5	591.5
9	1082	737.7	640.7	30	995	678.5	589.1
10	1078	734.9	638.3	31	991	675.6	586.8
11	1074	732.2	635.9	32	987	672.6	584.4
12	1070	729.5	633.6	33	982	669.7	581.4
13	1066	726.8	631.2	34	978	666.7	579.1
14	1062	724.0	628.8	35	973	663.7	576.1
15	1058	721.2	626.4	36	969	660.7	573.7
16	1054	718.5	624.1	36.090	968	660.3	573.2
17	1050	715.7	621.7	Above this altitude the speed of sound remains constant at this value.			
18	1046	712.9	619.3				
19	1041	710.1	616.4				
20	1037	707.3	614.0				

In the standard atmosphere used here the boundary between the troposphere and the stratosphere is set at 36,090 feet. In other tables it has been set at 35,332 feet.

A TABLE OF CONSTANTS

VALUES				RECIPROCAL			
π	3.14159	26535	89793	$\frac{1}{\pi}$	0.31830	98861	83791
$\frac{\pi}{2}$	1.57079	63267	94897	$\frac{2}{\pi}$	0.63661	97723	67582
2π	6.28318	53071	79586	$\frac{1}{2\pi}$	0.15915	49430	91895
π^2	9.86960	44010	89359	$\frac{1}{\pi^2}$	0.10132	11836	42338
$\sqrt{\pi}$	1.77245	38509	05516	$\frac{1}{\sqrt{\pi}}$	0.56418	95835	47756
$\sqrt{\frac{\pi}{2}}$	1.25331	41373	15500	$\sqrt{\frac{2}{\pi}}$	0.79788	45608	02865
$\sqrt{2\pi}$	2.50662	82746	31001	$\frac{1}{\sqrt{2\pi}}$	0.39894	22804	01433
e	2.71828	18284	59045	$\frac{1}{e}$	0.36787	94411	71442
e^2	7.38905	60989	70650	$\frac{1}{e^2}$	0.13533	52832	36613
\sqrt{e}	1.64872	12707	00128	$\frac{1}{\sqrt{e}}$	0.60653	06597	12639
$\log 10^e$	0.43429	44819	03252	$\log_e 10$	2.30258	50929	94046

$$g = 32.174 \text{ ft/sec}^2 = 10.725 \text{ yds/sec}^2$$

$$\rho_0 = .07513 \text{ lbs/ft}^3 = .002335 \text{ slugs/ft}^3$$

$$1 \text{ statute mile} = 5280 \text{ ft.} \quad 1 \text{ nautical mile} = 6080 \text{ ft.}$$

$$1 \text{ radian} = 57.29577 \quad 95130 \quad 82321 \text{ degrees.}$$

$$1 \text{ degree} = 0.01745 \quad 32925 \quad 19943 \text{ radians.}$$

BALLISTIC RELATIVE AIR DENSITY
versus
ALTITUDE in the NACA Standard Atmosphere

Conversion Factor = 1.018368

At 35332 ft. BRAD = .3114

h(ft)	0	100	200	300	400	500	600	700	800	900
0	1.0184	1.0154	1.0125	1.0095	1.0066	1.0036	1.0006	.9977	.9947	.9918
1000	.9888	.9859	.9830	.9801	.9772	.9744	.9715	.9687	.9658	.9630
2000	.9601	.9573	.9544	.9516	.9487	.9459	.9431	.9403	.9375	.9347
3000	.9319	.9291	.9263	.9236	.9208	.9181	.9153	.9126	.9098	.9071
4000	.9044	.9017	.8990	.8963	.8936	.8909	.8882	.8855	.8828	.8801
5000	.8774	.8748	.8721	.8695	.8668	.8642	.8616	.8590	.8564	.8538
6000	.8512	.8486	.8460	.8434	.8409	.8383	.8357	.8331	.8306	.8280
7000	.8255	.8230	.8205	.8180	.8154	.8129	.8104	.8079	.8054	.8029
8000	.8004	.7979	.7954	.7929	.7905	.7880	.7856	.7831	.7807	.7783
9000	.7759	.7735	.7711	.7687	.7663	.7639	.7615	.7591	.7567	.7543
10000	.7520	.7496	.7473	.7449	.7426	.7403	.7379	.7356	.7332	.7309
11000	.7286	.7263	.7240	.7217	.7194	.7171	.7148	.7126	.7103	.7081
12000	.7058	.7036	.7014	.6991	.6969	.6946	.6924	.6902	.6880	.6857
13000	.6835	.6813	.6791	.6769	.6748	.6726	.6704	.6683	.6661	.6640
14000	.6618	.6597	.6576	.6554	.6533	.6511	.6490	.6469	.6448	.6427
15000	.6406	.6385	.6365	.6344	.6323	.6303	.6282	.6262	.6242	.6221
16000	.6200	.6179	.6159	.6139	.6118	.6098	.6078	.6058	.6039	.6019
17000	.5999	.5979	.5959	.5939	.5919	.5899	.5880	.5861	.5841	.5822
18000	.5803	.5783	.5764	.5745	.5725	.5706	.5687	.5667	.5648	.5629
19000	.5610	.5592	.5574	.5555	.5536	.5518	.5499	.5480	.5462	.5443
20000	.5425	.5406	.5387	.5369	.5351	.5333	.5315	.5297	.5279	.5261
21000	.5243	.5225	.5207	.5189	.5171	.5154	.5136	.5118	.5100	.5083
22000	.5065	.5048	.5031	.5013	.4996	.4979	.4961	.4944	.4927	.4910
23000	.4893	.4876	.4859	.4842	.4825	.4808	.4791	.4775	.4758	.4742
24000	.4725	.4709	.4693	.4676	.4659	.4643	.4626	.4610	.4594	.4578
25000	.4562	.4546	.4529	.4513	.4497	.4482	.4466	.4450	.4435	.4419
26000	.4403	.4387	.4371	.4356	.4340	.4325	.4310	.4294	.4278	.4263
27000	.4248	.4233	.4218	.4203	.4188	.4172	.4157	.4142	.4127	.4112
28000	.4097	.4082	.4067	.4052	.4038	.4024	.4009	.3995	.3980	.3965
29000	.3950	.3936	.3922	.3907	.3893	.3879	.3864	.3850	.3836	.3822
30000	.3808	.3794	.3780	.3766	.3753	.3739	.3725	.3711	.3697	.3683

BALLISTIC RELATIVE AIR DENSITY
versus
ALTITUDE in the NACA Standard Atmosphere

Conversion Factor = 1.018368

At 35332 ft. BRAD = .3114

h(ft)	0	100	200	300	400	500	600	700	800	900
31000	.3669	.3656	.3643	.3629	.3616	.3602	.3589	.3575	.3562	.3549
32000	.3536	.3522	.3509	.3495	.3482	.3469	.3456	.3443	.3430	.3417
33000	.3404	.3392	.3379	.3366	.3353	.3341	.3328	.3315	.3303	.3290
34000	.3278	.3265	.3253	.3240	.3228	.3215	.3203	.3191	.3179	.3167
35000	.3155	.3143	.3130	.3117	.3104	.3089	.3075	.3060	.3046	.3031
36000	.3017	.3002	.2988	.2974	.2959	.2945	.2931	.2917	.2903	.2890
37000	.2876	.2862	.2848	.2835	.2821	.2808	.2794	.2781	.2768	.2755
38000	.2742	.2729	.2716	.2703	.2690	.2677	.2664	.2651	.2639	.2626
39000	.2614	.2601	.2589	.2576	.2564	.2552	.2540	.2528	.2516	.2504
40000	.2492	.2480	.2469	.2457	.2445	.2433	.2421	.2409	.2398	.2387
41000	.2375	.2364	.2352	.2341	.2330	.2319	.2308	.2297	.2286	.2275
42000	.2264	.2253	.2242	.2232	.2221	.2210	.2200	.2189	.2179	.2169
43000	.2159	.2149	.2139	.2128	.2118	.2108	.2098	.2088	.2078	.2068
44000	.2058	.2048	.2038	.2028	.2018	.2009	.1999	.1990	.1980	.1971
45000	.1961	.1952	.1943	.1934	.1925	.1916	.1906	.1897	.1888	.1879
46000	.1870	.1861	.1852	.1844	.1835	.1826	.1818	.1809	.1800	.1792
47000	.1783	.1774	.1766	.1758	.1750	.1741	.1733	.1725	.1717	.1708
48000	.1700	.1692	.1684	.1676	.1668	.1660	.1652	.1644	.1636	.1628
49000	.1620	.1613	.1605	.1598	.1590	.1583	.1575	.1568	.1560	.1552
50000	.1545	.1538	.1530	.1523	.1515	.1508	.1501	.1495	.1488	.1481
51000	.1474	.1466	.1459	.1452	.1445	.1438	.1431	.1424	.1418	.1411
52000	.1405	.1398	.1391	.1384	.1378	.1371	.1365	.1358	.1351	.1345
53000	.1338	.1332	.1326	.1320	.1314	.1308	.1301	.1295	.1289	.1283
54000	.1276	.1270	.1264	.1258	.1252	.1246	.1240	.1235	.1229	.1223
55000	.1217	.1211	.1206	.1200	.1194	.1188	.1183	.1178	.1172	.1166
56000	.1161	.1155	.1150	.1144	.1139	.1133	.1127	.1122	.1117	.1112
57000	.1107	.1101	.1096	.1091	.1086	.1080	.1075	.1070	.1065	.1060
58000	.1055	.1050	.1045	.1040	.1035	.1030	.1025	.1020	.1015	.1010
59000	.1005	.1001	.09962	.09914	.09865	.09817	.09770	.09724	.09678	.09632
60000	.09586	.09540	.09494	.09449	.09405	.09360	.09315	.09270	.09226	.09183
61000	.09139	.09095	.09051	.09008	.08966	.08923	.08880	.08838	.08796	.08754
62000	.08712	.08670	.08629	.08587	.08546	.08506	.08466	.08426	.08386	.08346
63000	.08306	.08266	.08226	.08187	.08148	.08109	.08071	.08032	.07994	.07955
64000	.07918	.07880	.07843	.07806	.07768	.07731	.07694	.07657	.07620	.07584

* Change from troposphere to stratosphere.

ROC 6

ALTITUDE (Feet) in the NACA Standard Atmosphere
versus
BALLISTIC RELATIVE AIR DENSITY

Conversion Factor = 1.018368

At BRAD = .3114; h = 35332 ft.

	0	1	2	3	4	5	6	7	8	9
.10	59110	58900	58700	58500	58300	58100	57900	57700	57500	57311
.11	57122	56934	56748	56563	56379	56196	56014	55834	55655	55477
.12	55300	55120	54947	54776	54607	54439	54272	54106	53943	53780
.13	53619	53460	53300	53140	52982	52826	52671	52517	52364	52212
.14	52061	51911	51762	51615	51469	51324	51180	51037	50895	50754
.15	50614	50475	50336	50200	50067	49933	49800	49667	49533	49400
.16	49267	49133	49000	48875	48750	48625	48500	48375	48250	48125
.17	48000	47882	47762	47640	47520	47400	47276	47153	47035	46917
.18	46800	46688	46574	46458	46342	46226	46112	46000	45889	45778
.19	45667	45559	45452	45343	45233	45122	45011	44905	44800	44695
.20	44589	44484	44380	44280	44180	44080	43980	43880	43780	43680
.21	43580	43480	43382	43280	43189	43090	42990	42890	42791	42695
.22	42600	42503	42410	42314	42220	42127	42036	41945	41855	41764
.23	41673	41582	41491	41400	41309	41218	41130	41043	40957	40870
.24	40784	40700	40616	40530	40443	40359	40275	40190	40104	40018
.25	39833	39850	39767	39683	39600	39516	39433	39352	39272	39192
.26	39112	39032	38952	38872	38792	38712	38632	38554	38477	38400
.27	38323	38246	38169	38092	38015	37938	37862	37785	37708	37631
.28	37558	37481	37407	37333	37259	37186	37114	37043	36970	36896
.29	36822	36750	36679	36607	36536	36464	36393	36324	36255	36186
.30	36117	36048	35979	35910	35841	35772	35703	35634	35566	35497
.31	35428	35359	35282	35200	35120	35040	34958	34875	34792	34708
.32	34625	34544	34464	34384	34304	34224	34144	34064	33984	33904
.33	33824	33744	33664	33584	33504	33425	33347	33269	33191	33112
.34	33033	32954	32877	32800	32723	32646	32569	32492	32416	32341
.35	32267	32193	32119	32044	31969	31892	31816	31741	31667	31593
.36	31519	31444	31370	31296	31220	31144	31069	30995	30922	30850
.37	30778	30707	30636	30564	30493	30420	30346	30272	30200	30129
.38	30057	29986	29914	29843	29771	29700	29629	29560	29491	29421
.39	29350	29280	29212	29142	29071	29000	28933	28867	28800	28733
.40	28664	28594	28526	28456	28386	28316	28248	28180	28113	28047
.41	27980	27913	27847	27780	27713	27647	27580	27514	27450	27386
.42	27320	27253	27187	27120	27053	26987	26920	26853	26789	26726
.43	26663	26600	26533	26467	26400	26337	26273	26208	26144	26081
.44	26019	25956	25894	25830	25765	25700	25637	25574	25511	25447
.45	25383	25319	25256	25194	25132	25071	25011	24950	24888	24825
.46	24762	24700	24638	24576	24516	24455	24394	24335	24276	24217
.47	24156	24094	24037	23971	23911	23850	23788	23728	23668	23607
.48	23547	23488	23429	23371	23312	23253	23194	23135	23076	23016
.49	22959	22900	22841	22782	22724	22665	22607	22550	22493	22435
.50	22377	22319	22262	22205	22147	22088	22029	21972	21916	21858
.51	21800	21744	21689	21633	21577	21521	21464	21407	21350	21294
.52	21239	21183	21128	21072	21017	20961	20906	20850	20794	20739
.53	20683	20628	20572	20517	20461	20406	20350	20294	20239	20184
.54	20131	20078	20025	19972	19918	19863	19808	19754	19700	19647

* Change from troposphere to stratosphere.

ALTITUDE (Feet) in the NACA Standard Atmosphere
versus
BALLISTIC RELATIVE AIR DENSITY

Conversion Factor = 1.018368

At BRAD = .3114; h = 35332 ft.

	0	1	2	3	4	5	6	7	8	9
.55	19594	19541	19488	19434	19380	19326	19273	19219	19164	19109
.56	19054	19000	18947	18895	18842	18789	18737	18685	18634	18583
.57	18531	18479	18427	18375	18324	18272	18220	18168	18116	18065
.58	18014	17963	17911	17858	17805	17755	17704	17652	17600	17548
.59	17496	17445	17395	17345	17295	17245	17195	17145	17095	17045
.60	16995	16945	16895	16845	16795	16742	16690	16640	16590	16540
.61	16490	16440	16391	16343	16294	16245	16195	16145	16096	16048
.62	16000	15952	15905	15857	15809	15760	15710	15660	15611	15562
.63	15514	15465	15416	15367	15319	15271	15223	15174	15125	15077
.64	15029	14981	14933	14885	14838	14790	14743	14695	14648	14600
.65	14552	14505	14459	14413	14367	14320	14273	14227	14180	14133
.66	14086	14039	13992	13946	13900	13853	13806	13759	13713	13667
.67	13620	13574	13528	13482	13436	13389	13342	13295	13250	13205
.68	13159	13114	13068	13023	12977	12932	12886	12844	12800	12755
.69	12709	12664	12618	12573	12528	12483	12439	12395	12350	12305
.70	12261	12217	12172	12127	12082	12037	11992	11948	11904	11859
.71	11814	11770	11726	11681	11636	11592	11548	11504	11461	11417
.72	11374	11330	11287	11243	11200	11157	11113	11070	11026	10983
.73	10939	10896	10852	10809	10767	10725	10682	10639	10596	10554
.74	10512	10469	10426	10383	10339	10296	10254	10212	10169	10126
.75	10084	10042	10000	9957	9914	9872	9830	9788	9746	9704
.76	9662	9621	9579	9538	9496	9454	9412	9371	9329	9288
.77	9246	9204	9162	9120	9079	9038	8996	8954	8912	8871
.78	8829	8788	8746	8705	8664	8623	8582	8541	8500	8460
.79	8420	8379	8338	8297	8256	8216	8176	8136	8096	8056
.80	8016	7976	7936	7896	7856	7816	7776	7736	7696	7656
.81	7616	7576	7536	7496	7456	7417	7378	7339	7300	7260
.82	7220	7180	7140	7100	7060	7020	6980	6940	6900	6862
.83	6823	6784	6744	6704	6665	6627	6588	6550	6512	6473
.84	6435	6396	6356	6316	6277	6238	6200	6162	6123	6085
.85	6046	6008	5969	5931	5892	5853	5814	5776	5738	5700
.86	5662	5623	5585	5546	5508	5469	5431	5393	5356	5318
.87	5280	5242	5204	5167	5130	5092	5054	5016	4978	4941
.88	4904	4867	4830	4793	4756	4719	4681	4644	4607	4570
.89	4533	4496	4459	4422	4385	4348	4311	4274	4237	4200
.90	4163	4126	4089	4052	4015	3978	3941	3904	3867	3830
.91	3793	3757	3721	3685	3648	3611	3575	3539	3503	3467
.92	3430	3393	3357	3321	3285	3248	3211	3175	3139	3104
.93	3068	3032	2996	2961	2925	2889	2854	2818	2782	2748
.94	2711	2675	2639	2604	2568	2532	2496	2461	2425	2390
.95	2355	2320	2285	2250	2215	2180	2145	2110	2075	2039
.96	2004	1969	1934	1900	1864	1829	1794	1759	1724	1689
.97	1654	1618	1583	1548	1513	1478	1443	1407	1372	1337
.98	1303	1269	1234	1200	1165	1131	1097	1062	1028	994
.99	960	926	892	858	824	790	757	723	689	655
1.00	621	587	553	520	487	453	420	386	352	318
1.01	284	250	216	182	148	114	80	47	13	

FIRING TABLE ANGLES

Firing tables are usually tabulated at every 22.5° for the azimuth and zenith angles, A_0 and Z_0 . In fire control theories it is frequently necessary to employ various combinations of the trigonometric functions of these angles and their corresponding single angle, θ . Values of θ and a group of trigonometric functions are therefore exhibited on these pages. The elevation angle $E_0 = 90^\circ - Z_0$.

VALUES OF θ CORRESPONDING TO GIVEN A_0 AND Z_0

$$\cos \theta = \sin Z_0 \cos A_0$$

$Z_0 \backslash A_0$	0	22.5	45	67.5	90	112.5	135	157.5	180
0	90	90	90	90	90	90	90	90	90
22.5	67.5000	69.2952	74.3001	81.5789	90	98.4211	105.6999	110.7048	112.5000
45	45.0000	49.2105	60.0000	74.3001	90	105.6999	120.0000	130.7895	135.0000
67.5	22.5000	31.3997	49.2105	69.2952	90	110.7048	130.7895	148.6003	157.5000
90	0	22.5000	45.0000	67.5000	90	112.5000	135.0000	157.5000	180.0000
112.5	22.5000	31.3997	49.2105	69.2952	90	110.7048	130.7895	148.6003	157.5000
135	45.0000	49.2105	60.0000	74.3001	90	105.6999	120.0000	130.7895	135.0000
157.5	67.5000	69.2952	74.3001	81.5789	90	98.4211	105.6999	110.7048	112.5000
180	90	90	90	90	90	90	90	90	90

TRIGONOMETRIC FUNCTIONS OF θ

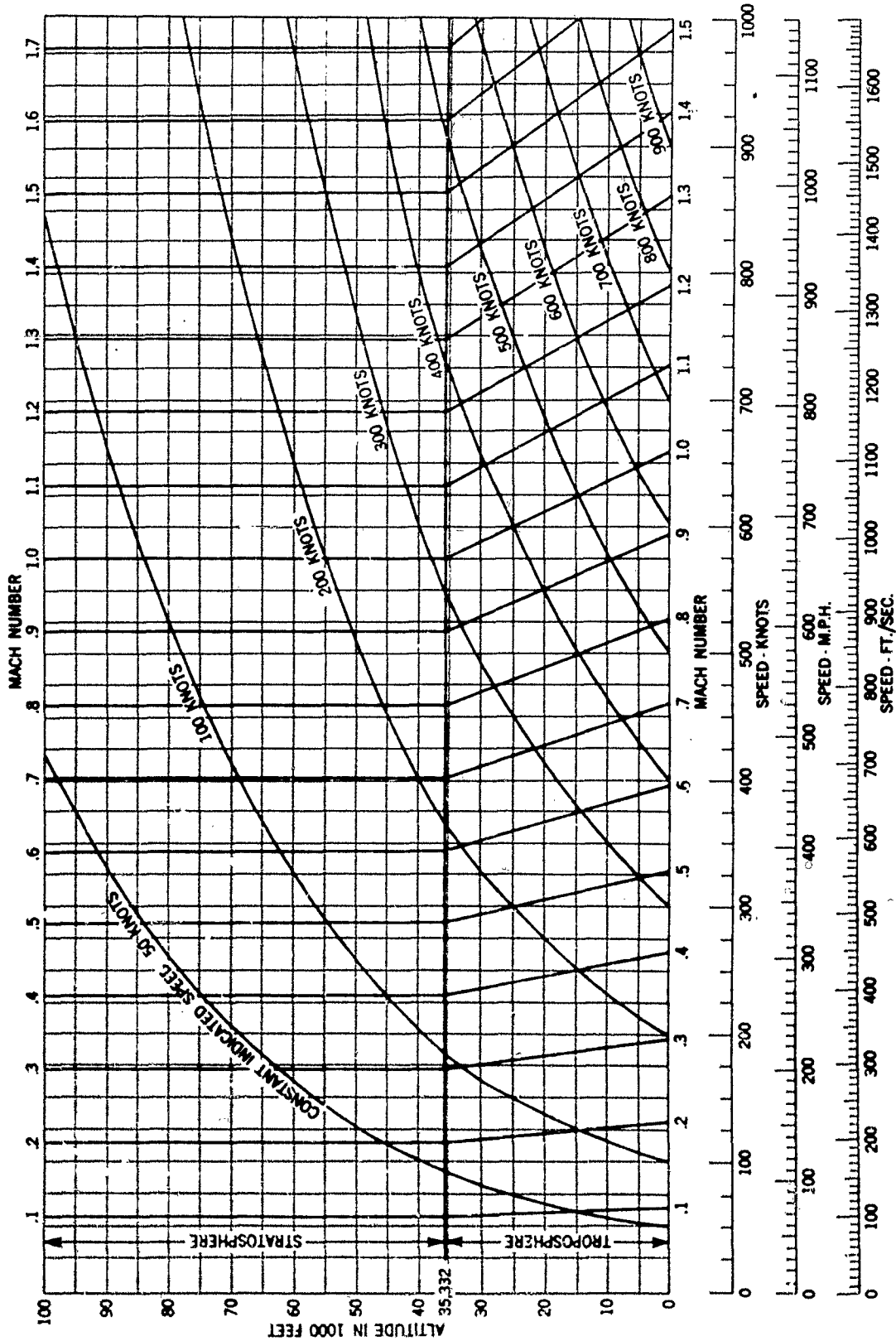
θ	$\sin \theta$	$\cos \theta$
0	0	1
22.5000	.382683433	.923879533
31.3997	.521005382	.853553391
45.0000	.707106781	.707106781
49.2105	.757115119	.653281483
60.0000	.866025403	.500000000
67.5000	.923879533	.382683433
69.2952	.935414346	.353553391
74.3001	.962692419	.270598050
81.5789	.989218575	.146446610
90	1	0

θ	$\sin \theta$	$\cos \theta$
90	1	0
98.4211	.989218575	-.146446610
105.6999	.962692419	-.270598050
110.7048	.935414346	-.353553391
112.5000	.923879533	-.382683433
120.0000	.866025403	-.500000000
130.7895	.757115119	-.653281483
135.0000	.707106781	-.707106781
148.6003	.521005382	-.853553391
157.5000	.382683433	-.923879533
180	0	-1

TRIGONOMETRIC FUNCTIONS OF A, Z

Z \ A	0	22.5	45	67.5	90	112.5	135	157.5	180
sin	0	.382683433	.707106781	.923879533	1	.923879533	.707106781	.382683433	0
cos	1	.923879533	.707106781	.382683433	0	-.382683433	-.707106781	-.923879533	-1
$\sin A \sin A = \cos Z \sin A$									
0	0	0	0	0	0	0	0	0	0
22.5	0	.146446610	.270598050	.353553391	.382683433	.353553391	.270598050	.146446610	0
45	0	.270598050	.500000000	.653281483	.707106781	.653281483	.500000000	.270598050	0
67.5	0	.353553391	.653281483	.823879533	.923879533	.823879533	.653281483	.353553391	0
90	0	.382683433	.707106781	.923879533	1	.923879533	.707106781	.382683433	0
112.5	0	.353553391	.653281483	.823879533	.923879533	.823879533	.653281483	.353553391	0
135	0	.270598050	.500000000	.653281483	.707106781	.653281483	.500000000	.270598050	0
157.5	0	.146446610	.270598050	.353553391	.382683433	.353553391	.270598050	.146446610	0
180	0	0	0	0	0	0	0	0	0
$\sin Z \cos A = \cos Z \cos A$									
0	0	0	0	0	0	0	0	0	0
22.5	.382683433	.382683433	.270598050	.146446610	0	-.146446610	-.270598050	-.382683433	0
45	.707106781	.653281483	.500000000	.353553391	0	-.353553391	-.500000000	-.653281483	-.707106781
67.5	.923879533	.823879533	.653281483	.382683433	0	-.382683433	-.653281483	-.823879533	-.923879533
90	1	.923879533	.707106781	.382683433	0	-.382683433	-.707106781	-.923879533	-1
112.5	.923879533	.823879533	.653281483	.382683433	0	-.382683433	-.653281483	-.823879533	-.923879533
135	.707106781	.653281483	.500000000	.353553391	0	-.353553391	-.500000000	-.653281483	-.707106781
157.5	.382683433	.382683433	.270598050	.146446610	0	-.146446610	-.270598050	-.382683433	0
180	0	0	0	0	0	0	0	0	0
$\cos Z \sin A = \sin Z \sin A$									
0	0	0	.707106781	.923879533	1	.923879533	.707106781	.382683433	0
22.5	0	.382683433	.653281483	.823879533	.923879533	.823879533	.653281483	.382683433	0
45	0	.653281483	.823879533	.923879533	.923879533	.823879533	.653281483	.382683433	0
67.5	0	.823879533	.923879533	.923879533	.923879533	.823879533	.653281483	.382683433	0
90	0	.923879533	.923879533	.923879533	.923879533	.823879533	.653281483	.382683433	0
112.5	0	.923879533	.923879533	.923879533	.923879533	.823879533	.653281483	.382683433	0
135	0	.923879533	.923879533	.923879533	.923879533	.823879533	.653281483	.382683433	0
157.5	0	.923879533	.923879533	.923879533	.923879533	.823879533	.653281483	.382683433	0
180	0	.923879533	.923879533	.923879533	.923879533	.823879533	.653281483	.382683433	0
$\cos Z \cos A = \sin Z \cos A$									
0	1	.923879533	.707106781	.382683433	0	-.382683433	-.707106781	-.923879533	-1
22.5	.923879533	.923879533	.707106781	.382683433	0	-.382683433	-.707106781	-.923879533	-1
45	.707106781	.653281483	.500000000	.353553391	0	-.353553391	-.500000000	-.653281483	-.707106781
67.5	.382683433	.382683433	.270598050	.146446610	0	-.146446610	-.270598050	-.382683433	0
90	0	.382683433	.270598050	.146446610	0	-.146446610	-.270598050	-.382683433	0
112.5	0	.382683433	.270598050	.146446610	0	-.146446610	-.270598050	-.382683433	0
135	0	.382683433	.270598050	.146446610	0	-.146446610	-.270598050	-.382683433	0
157.5	0	.382683433	.270598050	.146446610	0	-.146446610	-.270598050	-.382683433	0
180	0	.382683433	.270598050	.146446610	0	-.146446610	-.270598050	-.382683433	0

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